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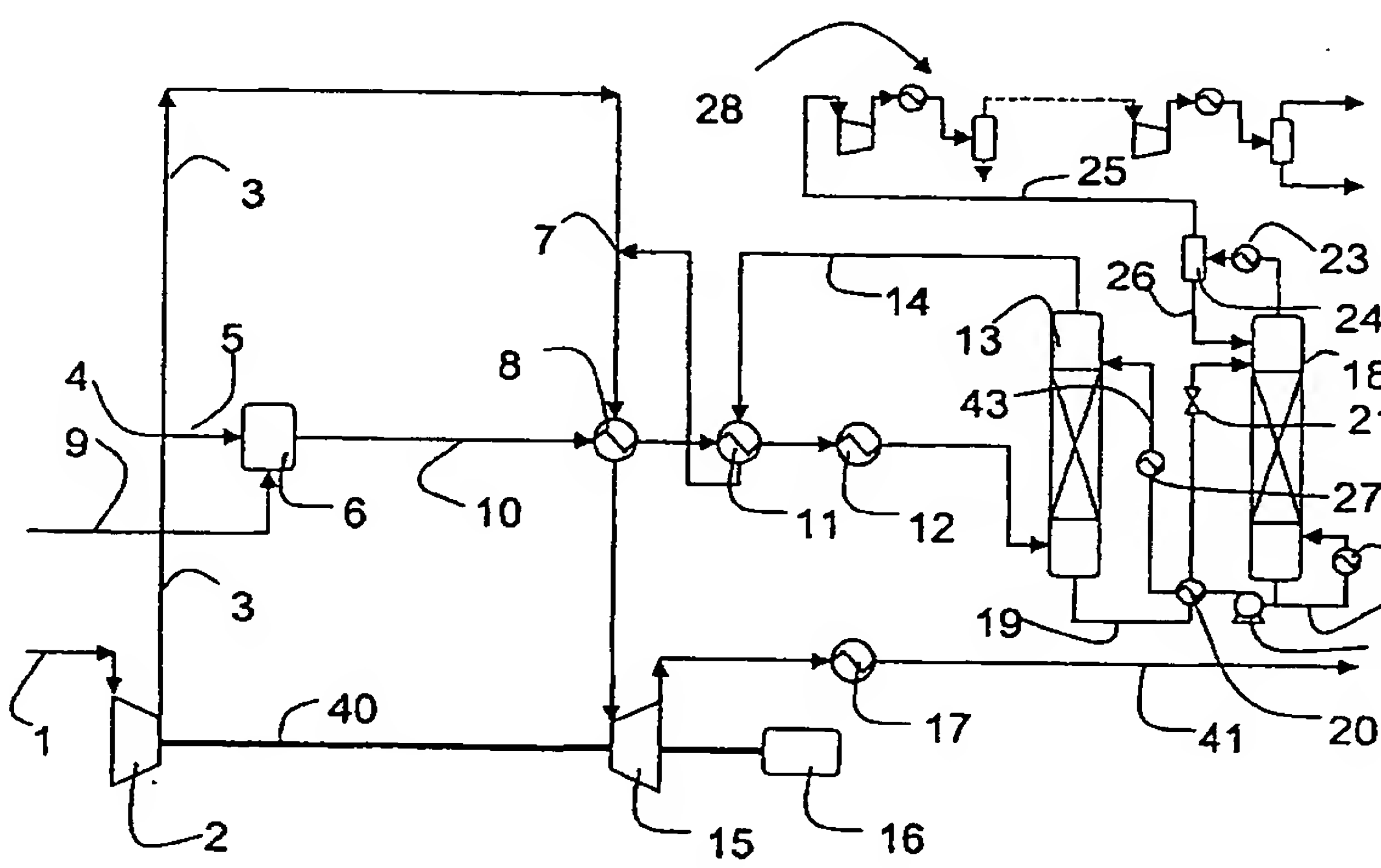

(57) Abstract

A method is described for controlling the CO_2 content in the flue gas from thermal power plants, in the case of combustion of carbon or other carbon–containing fuel and an oxygen–containing gas, in which the combustion takes place in a combustion chamber (6) and the combustion gas is separated into a CO_2 –rich flue gas and a flue gas with a low CO_2 content, where the CO_2 –rich flue gas may then be treated so as not to allow CO_2 to escape to the environment, which is characterised in that compressed air and fuel is fed to the combustion chamber (6), in which combustion takes place at an elevated pressure, the flue gas from the combustion is cooled and passed through a pressurised contacting device (13) in which CO_2 from the combustion is absorbed by an absorbent, the non–absorbed gas is led away as a gas stream with a low CO_2 content, compressed air is added, it is heated and depressurised across a gas turbine (15) before being released into the environment, and the absorbent is regenerated and recycled or removed for disposal. In addition, a thermal power plant for realisation of the method is described.

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Method for controlling the CO2 content flue gas from thermal power plants and a thermal power plant using the method

The present invention regards a method for controlling the content of CO_2 in flue gas discharged from a combustion chamber, before the gas is released, by obtaining a high partial pressure of CO_2 in the flue gas, together with a system for realisation of the method.

In recent years, the increased CO_2 content in the atmosphere, caused by combustion of fossil fuels such as oil, gas and coal, has received much attention due to its contribution to the green house effect and thereby global warming. The countries have, through international agreements, committed to reducing the CO_2-emissions, while fossil fuels remain the most important energy carriers.

Different solutions have been suggested for separating out CO_2 from the flue gas from combustion systems in order to reduce the amount of CO_2 discharged to the atmosphere, by binding or safe disposal of this gas. However such CO_2 separation is difficult and requires complex and costly equipment, not least because of the large amounts of gas in question and the relatively low concentrations of CO_2 in the flue gases from conventional combustion systems.

This situation is difficult due to the high, and steadily increasing, global demand for energy and the high availability of fossil fuels.

As such, an energy efficient, cost efficient, robust and simple method for removal of significant amounts of CO_2 from the flue gas would be desirable in order to ease this situation. The separated CO_2 may be disposed of e.g. in oil reservoirs, aquifers or possibly be dissolved in salt water and discharged at a great depth in the ocean, or alternatively be bound chemically and disposed of.

Flue gas from power plants typically contain from about 3 to 12 volume % CO_2, the lowest values being typical of gas turbines and the highest values being typical of combustion chambers being operated at conditions of almost complete combustion of oxygen.

The most common thing today is to ignore any environmental problems and release the combustion gas into the atmosphere. The alternatives comprise new and often costly technology, and are currently being evaluated or developed. The systems aim at a high partial pressure of CO_2 and a low volume flow of CO_2 -containing flue gas. The following alternatives may be mentioned:

- The flue gas from the combustion is contacted with a chemical solution, typically an amine solution, near or at atmospheric pressure. Some of the CO_2 is absorbed in the solution, which is then regenerated in a regeneration plant to give the original chemical solution, in addition to a gas with a relatively high content of CO_2. These systems aim at achieving an increased partial pressure of CO_2 and a reduced volume flow of CO_2-containing flue gas by recycling part of the flue gas. The effect is very limited. Such processes are therefore encumbered with problems linked to the size of the means that contact the gas with the chemical solution. Other problems are associated with contaminants in the combustion gas that are enriched in the chemical solution, as well as degradation of the chemical solution. Moreover, the regeneration requires a lot of energy. These problems make this process costly and complex.
- Conversion of the carbon compound-containing fuel into hydrogen and carbon dioxide. Here, use is made of process units called reformers. Reforming is a process that requires a lot of energy, and which produces hydrogen and CO_2. An increased partial pressure of CO_2 and a reduced volume flow of CO_2-containing gas is achieved because the reforming process takes place under pressure. This simplifies the separation of CO_2 and hydrogen after the reformer, so that CO_2 can be disposed of or taken care of in other ways as indicated above, and the hydrogen can be used as fuel. The hydrogen is then burned in a gas turbine in a power plant. However the total system becomes very complicated and costly, as it includes both a hydrogen generation plant and a power plant
- By separating air, so as to form oxygen and nitrogen, combustion may take place with near-pure oxygen instead of air. The system requires recycling of combustion gas and a gas turbine designed for a mixture of CO_2 and water vapour. When nitrogen has been removed, and the flue gas is recycled, an increased partial pressure of CO_2 and a reduced volume flow of CO_2 -containing gas to be cleaned results. Even if it is relatively simple to separate these two components, the total

costs for such a system will be relatively high, as it among other things requires an oxygen generation plant in addition to the power plant.

As such, there is a need for a method and a system that will overcome the problems mentioned.

According to the present invention, a method has been suggested for controlling the CO_2 –content of the flue gas from a thermal power plant when burning carbon or other carbon-containing fuels and air, in which the combustion takes place in a combustion chamber and the combustion gas is separated into a CO_2 –rich flue gas and a flue gas with a low CO_2 –content, and where the CO_2 –rich flue gas can then be treated in a way such that CO_2 does not escape to the environment, and which is characterised in
that compressed air and fuel are led to the combustion chamber in which the combustion takes place under an elevated pressure,
that the flue gas from the combustion is cooled and passed through a pressurised contacting device, where CO_2 from the combustion is absorbed by an absorbent,
that the non-absorbed gas is led away with a low content of CO_2, compressed air is added, the stream is heated and then depressurised across a gas turbine before being released to the environment, and
that the absorbent is regenerated and recycled, or removed for disposal.

The absorbent from the contacting device preferably passes to a desorption device, which is at a lower pressure and/or higher temperature than the contacting device, so that CO_2 is desorbed and a CO_2 –rich flue gas is led away for further treatment, and the absorbent is recycled through the contacting device.

It is also preferable that the flue gas from the combustion is cooled through heat exchange with compressed air and the stream with a low CO_2 content from the contacting device, before the flue gas passes into the contacting device.

Moreover, it is preferable that the gas stream with a low CO_2 –content from the contacting device is depressurised across a turbine after the gas has gone through a heat exchanger to be heated by the flue gas from the combustion chamber.

The absorbent is preferably a liquid, such as water, an amine solution or an inorganic solution.

In addition, a thermal power plant is described for combustion of carbon or carbon-containing materials, comprising a combustion device in which the carbon or carbon-containing material is combusted with air, a flue gas pipe for leading the combustion gas from the combustion chamber to a contacting device in which the flue gas is contacted with an absorbent that predominantly absorbs CO_2, and where the remaining gases in the flue gas are mainly not absorbed, a gas pipe for the non-absorbed gas stream with a low CO_2 content from the contacting device and means for depressurising the gas stream with a low CO_2 content before it is released to the environment, as well as means of transporting the absorbent containing dissolved CO_2 from the contacting device for disposal, or means of desorbing CO_2 for recycling the absorbent, which is characterised in that it comprises

a combustion chamber that has been designed for combustion of air and fuel at an elevated pressure,

a contacting device containing an absorbent that absorbs CO_2, and in which the remaining gases from the combustion are mainly not absorbed, so as to form a gas stream with a low CO_2-content and a stream with CO_2-enriched absorbent,

means of cooling the flue gas from the combustion before these reach the contacting device, as well as heating the stream with a low CO_2-content, and

a turbine for depressurising the stream with a low CO_2-content, where the turbine drives a generator for production of electric power.

It is preferable that the pressure in the combustion chamber is between about 1.5 and 30 bar, preferably between 10 and 18 bar.

It is also preferable that the thermal power plant comprise means of adding compressed air to the stream with a low CO_2-content, before this is depressurised across the turbine.

The thermal power plant preferably also comprises means of regenerating the absorbent in way so as to form a CO_2-rich stream that may be compressed for disposal or sale, and where the absorbent may be returned to the contacting device.

Air from the surroundings is compressed in a compressor. The compressed air stream is separated into two smaller streams, where one of these streams, together with a fuel containing carbon or carbon compounds, is fed to a combustion chamber in which combustion takes place under pressure. The still-pressurised flue gas from the combustion chamber, which gas contains CO_2 in addition to other compounds, is cooled first in a gas-gas heat exchanger in which the cooling medium is the other of the two air streams mixed with cleaned flue gas, then in another gas-gas heat exchanger in which the cooling medium is cleaned flue gas, and lastly in a trim cooler. The cooled and compressed flue gas is then contacted with an absorbent in a pressurised contacting device, in which a significant amount of the CO_2 is absorbed. From the contacting device, the pressurised flue gas with a reduced CO_2 –content is heated up again in the gas-gas heat exchanger and mixed with the other of the two air streams. This mixture is heated further in a gas-gas heat exchanger and expanded in an outlet gas turbine in which the energy in the pressurised gas is recovered. Residual heat in the expanded gas is recovered through heat exchange with water and water vapour before the gas is released into the atmosphere.

Important criteria for selecting an absorbent is its selectivity towards absorption of CO_2 above other gases in the flue gas, its stability vs. degradation caused by e.g. heat and contaminants, as well as the costs associated with the absorbent. It is preferable that the absorbent be a liquid, such as water, an amine solution or an inorganic solution.

The absorbent containing absorbed CO_2 is then preferably regenerated.

A known system is preferred, in which the absorbent from the contacting device is first depressurised and then possibly heated up before it is led to a desorption device, which is at a low pressure and possibly elevated temperature, and in which the absorbed CO_2 is desorbed and drawn out of the desorption device as a gas. This gas has a high concentration of CO_2 and can be handled in a known manner.

The solvent that is taken out of the desorption device, and which contains a greatly reduced amount of CO_2, is then cooled before being re-introduced to the contacting device under pressure, in order to pass through a new cycle.

The invention will now be described with reference to preferred embodiments and to the accompanying drawings, in which:

Figure 1	shows a schematic diagram of a preferred embodiment of the invention;
Figure 2	shows a schematic diagram of a second preferred embodiment of the invention,
Figure 3	shows a schematic diagram of a third preferred embodiment of the invention,
Figure 4	shows a schematic diagram of a fourth preferred embodiment of the invention,
Figure 5	shows a schematic diagram of a fifth preferred embodiment of the invention, and
Figure 6	shows a schematic diagram of a sixth preferred embodiment of the invention.

Example 1

The system shown in Figure 1 is a preferred system for realisation of the present method.

Air from air intake 1 is compressed in a compressor 2, and passed from this through an air pipe 3. The air stream in the air pipe 3 is divided into two at a branching 4, where one part continues in air pipe 3 to a mixing device 7, a heat exchanger 8 and onwards to a turbine 15, while the other part, as an example 25 to 95% of the total air stream, is fed through a pipe 5 to a combustion chamber 6. The branching 4 is provided with pressure reducing means (not shown), so as to make the pressure of the air in the mixing device 7 equal to the pressure of the cleaned gas it is mixed with in the mixing device 7.

Fuel containing carbon or carbon compounds, for instance hydrocarbons such as oil or gas, is fed to the combustion chamber 6 through fuel feed 9. The design of the combustion chamber is based on prior art, and will be dependent on the type of fuel used. The use of gas or liquid fuels normally entails use of a commonly used combustion chamber, whereas combustion chambers of the fluidised bed type are preferred when using powdered fuels.

The combustion in the combustion chamber 6 takes place under pressure, for instance in the order of 8 to 30 bar and more preferably in the range from 13 to 18 bar. The combustion chamber 6 and the supply of air and fuel from pipe 5 and fuel feed 9 respectively, are controlled in a manner so as to ensure maximum utilisation of the oxygen during combustion. The amount of oxygen consumed during combustion is limited by conditions of temperature and materials, and may be optimised through the detailed design of the system, so as to achieve the highest possible partial pressure of CO_2 in the flue gas. How much of the oxygen in place that is used in the combustion chamber in the present arrangement varies based on operational and constructional parameters. Preferably from about 50 % to 95% of the oxygen is consumed during the combustion in the combustion chamber. This differs from a gas turbine, in which it is difficult to consume more than approximately 25% of the oxygen during combustion.

The flue gas from the combustion chamber 6 is passed through a flue gas pipe 10 through a gas-gas heat exchanger 8, a further gas-gas heat exchanger 11, and a trim cooler 12, where the flue gas is cooled before being fed into a contacting device 13 in which the gas is contacted with an absorbent. The pressure in the contacting device 13 is relatively high, and is close to the pressure in the combustion chamber 6, as the pressure is only reduced by an amount corresponding to the pressure drop through heat exchangers 8 and 11 and trim cooler 12. This ensures a high partial pressure of CO_2 and a relatively low total volume flow of gas, and is highly important in order to ensure efficient CO_2 absorption and a moderately dimensioned contacting device.

The temperature in the contacting device 13 is important. Based on prior art and considering the fact that the absorbent must be able to dissolve the maximum amount of CO_2 , while at the same time the dissolution process must be relatively quick, the temperature is preferably in the range from 30 to 120°C.

Temperatures in the range from 50 to 70°C are most preferred. Low temperatures are preferred when the absorbent is water or amine, whereas the temperature may be somewhat higher when the absorbent is an inorganic solution, such as potassium carbonate. Under no circumstances must the temperature be so low that there is a risk of ice or hydrates forming.

The preferred absorbents are liquids such as water, an amine solution or an inorganic aqueous solution, which under high pressure and a high partial pressure of CO_2 can absorb relatively large amounts of CO_2 at an acceptable absorption rate. Preferably, the absorbent trickles down a large internal contacting surface inside the contacting device 13, counter current to the direction of gas flow.

Besides the fact that water as an absorbent is environmentally friendly, in that no potentially dangerous chemicals are added, the addition of water from the combustion gas will not be a source of contamination of the absorbent. By using water as an absorbent, there will also not be any continuous concentration of possible contaminants in the water, as water may continuously be drawn off in an amount corresponding to the amount of water added through the flue gas from the combustion. However water has a low capacity for absorbing CO_2 when compared with amines or an aqueous solution of potassium carbonate.

The gas from the flue gas which is not absorbed in the solvent is led from the contacting device into a gas pipe 14 leading to the gas-gas heat exchanger 11, where it is heated before the gas is mixed with air from air pipe 3 in the mixing device 7. The mixture of air and cleaned gas is fed to gas-gas heat exchanger 8, in which it is heated to a temperature of 650°C or higher. Preferred temperature is between 800 and 900°C.

The gas-gas heat exchanger 8 is based on materials and a design suitable for relatively high temperatures. After passing through the gas-gas heat exchanger 8, the hot high-pressure gas is depressurised in a turbine 15. The kinetic energy from the turbine 15 may be used in various ways, for instance as shown in the figure, where the turbine 15 is connected to the compressor 1 via a common shaft 40 and supplies this with all the energy required to compress the air before it is fed to the combustion chamber 6. In addition, this kinetic energy will be sufficient to drive other units in the system, the preferred unit being electrical generator 16.

The figure shows a system where flue gas from the turbine 15 is led through a discharge pipe 41 through a heat exchanger 17 in which residual heat is utilised for instance for heating water or producing steam, before the cleaned gas is released from the system. The flue gas from the turbine will typically have a molecular weight of between 26 and 30 g/mole.

The steam produced from heat exchanger 17 may for instance be used to supply energy to circulation reboiler 22 and, depending on the available amount, also for running a steam turbine (not shown).

The figure shows a system in which the absorbent, such as amine or an aqueous solution of potassium carbonate, is recovered and recycled in the process. If possible or if so desired, it is however possible to imagine water being used as an absorbent, that water containing CO_2 gas is released into the sea at great depths, and that new water is fed into the contacting device 13 instead of recycling the water. In this case, seawater may be used as an absorbent, and the system will not comprise a desorption device 18.

In the arrangement shown, a CO_2-containing solvent that can be regenerated, typically amine or an aqueous solution of potassium carbonate, is led from the contacting device 13 via a pipe 19, via a heat exchanger 20 and via a depressurising device 21, and into the top of the desorption device 18. The pressure in the desorption device is dependent on the choice of absorbent, the amount of CO2 absorbed and regeneration requirements. It will normally be lower than the pressure in the contacting device 13, and will normally be approximately equal to the ambient pressure.

In order to increase the liberation of absorbed gas from the absorbent in the desorption device 18, a portion of the absorbent will normally be removed in the bottom of the desorption device and be passed through a circulation pipe 44 through a circulation reboiler 22, where the absorbent is heated prior to being led back to the desorption device 18. The energy requirement of the circulation reboiler 22 is completely or partially met by using heat that has been recovered in the heat exchanger 17. The requirement of this circulation reboiler is minimised, as the contacting device 13 operates with a high partial pressure of CO_2 in the incoming gas.

CO_2-rich gas that is released in the desorption device 18 is removed at the top of this, and is then preferably led through a condenser 23 and a liquid separator 24, before being passed through CO_2 pipe 25 as a CO_2 –rich gas stream. Liquid that is separated out in liquid separator 24 is returned to the desorption device through a liquid pipe.

Regenerated absorbent from the bottom of the desorption device 18 is removed and pumped through a recirculation pipe 43 by a pump 42, cooled in heat exchanger 20 and then cooled further in trim cooler 27, before being returned to the absorption device 13.

The CO_2 –rich gas stream from the liquid separator 24 is passed to a compressor system 28 through a CO_2 pipe 25, which compressor system consists of one or several compression stages in which the gas is compressed in a manner so as to allow it to be disposed of safely or sold. The compressor system 28 shown comprises several stages, is of a known type, and will therefore not be described in greater detail herein. Typically, from about 80 – 95% of the CO_2 in the flue gas from the combustion will be contained in this CO_2 –rich gas stream, all according to system design and control parameters.

The gas that is led out of the contacting device with a low CO_2 content, typically about 10% of the total CO_2 produced during the combustion, is in the system shown depressurised across a turbine 15 after being heated in the heat exchanger 11, mixed with compressed air in the mixing device 7 and heated further in heat exchanger 8. The heating and the depressurisation across the turbine 15 is preferred in order to utilise the pressure and thermal energy in the flue gas, and thereby improve the profitability of the system, and is normally required in order for the system to function as intended. In order to further increase the energy utilisation, and to improve the cooling capacity of the gas with a low CO_2 content downstream of the contacting device 13, a component may be added to the gas in order to increase its heat capacity, such as water or steam, before the gas is passed through the heat exchanger 8.

Example 2

Figure 2 shows an alternative embodiment of the present invention. This embodiment will in many cases be preferably to the embodiment in example 1, as the total efficiency will generally be greater.

As such, the basic principles of this embodiment are the same as for the embodiment described in the previous example. Here however, measures have been implemented to optimise efficiency.

The gas that is led out of the contacting device 13, and which has a low CO_2 content, is compressed in a compressor 29 before being fed to gas-gas heat exchanger 11 and heated up. An electrically driven compressor 29 is preferred. This compensates for the pressure drop through the combustion chamber 6, the pressure drop in the flue gas through gas-gas heat exchangers 8 and 11, the pressure drop in the gas through trim cooler 12, the pressure drop through the contacting device 13, and the pressure drop in the cleaned gas through gas-gas heat exchanger 11. The total pressure drop will typically be 5 bar or less. The work done on compression by compressor 29 will be relatively little, because gas from the contacting device 13 is at a relatively high pressure and a relatively low temperature. The amount of gas to be compressed is moderate, because only a portion of the compressed air from compressor 2 is fed to compressor 29 via the combustion chamber 6, via gas-gas heat exchangers 8 and 11, via trim cooler 12 and via the contacting device 13. The amount of gas is also moderate because CO_2 and partly water vapour has been removed from this gas in contacting device 13.

The compressor 29 makes it possible to raise the pressure in the mixing device 7 to near the outlet pressure from the compressor 2. Thus, there will be no need to lower the pressure in the air pipe 3 at the pressure reducing means associated with the branching 4, which is mentioned but not shown in Figure 1. By compressing a moderate amount of cold gas, a higher pressure is achieved for a large amount of hot gas to the expansion turbine 15. The increased output from the expansion turbine 15 will therefore exceed the energy requirement from the compressor 29, and as such give a net increase in output from the system.

Example 3

Figure 3 shows a third preferred embodiment of the present invention. This embodiment is based on the embodiments described in examples 1 and 2, with the added feature of removal of some water vapour from the gas in liquid separator 30, which water vapour is produced during combustion in combustion chamber 6, especially when using fuels containing a lot of hydrogen in addition to the carbon, such as natural gas, and especially when the air fed to the combustion chamber 6 is combusted to a low residual amount of oxygen. This occurs because some of the water vapour in many cases will condense and form water after the overall cooling of the flue gas from combustion chamber 6 in gas-gas heat exchangers 8 and 11 and in trim cooler 12.

Gas from liquid separator 30 is fed to the contacting device 13 via a flue gas pipe 46. Water from liquid separator 30 is drawn off through a liquid pipe 45 and is pumped via pump 31, mainly past drain valve 33 and into mixing device 32, where the water is mixed with cleaned gas from the contacting device. Mixing water into cleaned gas achieves a greater mass flow to the cold side of gas-gas heat exchanger 11. Gas-gas heat exchanger 11 achieves a higher capacity for cooling outlet gas from combustion chamber 6, which gas is passed via gas-gas heat exchanger 8. Thus the heat loss in trim cooler 12 is reduced, and the system efficiency is increased. Water evaporates in gas-gas heat exchanger 11 and increases the volume flow of gas to gas turbine 15.

Example 4

Figure 4 shows a fourth preferred embodiment of the present invention. This embodiment is based on the embodiments described in examples 1, 2 and 3, with the added feature that up to 75% of the outlet gas from the combustion chamber 6, after being cooled in gas-gas heat exchanger 8, is returned to combustion chamber 6 via pipe 34 and compressor 35. An electrically driven compressor is preferred. At the same time, the distribution of compressed air in branching 4 is altered in a manner such that a relatively small amount of air, down to 25% of the total amount of air from compressor 2, is fed to the combustion chamber 6 via pipe 5.

In order to maintain the total amount of energy produced through combustion in combustion chamber 6, a major part of the oxygen that is fed to the combustion chamber 6 with the air through pipe 5 is combusted. This gives an increased concentration of CO_2 in the outlet gas from the combustion chamber, while cooled outlet gas recycled via compressor 15 prevents the outlet gas from the combustion chamber from becoming too hot.

A significant advantage of this system is the fact that the concentration of CO_2 in the gas stream passed on through gas-gas heat exchanger 11, via trim cooler 12 and liquid separator 30 to contacting device 13 is increased, while the total volume flow is reduced. This gives a significant increase in efficiency and a reduction in the physical dimensions of contacting device 13.

Another and surprising effect that is achieved as a result of returning some cooled outlet gas from combustion chamber 6 via pipe 10 and gas-gas heat exchanger 8 back to combustion chamber 6, is that the output of gas turbine 15 increases. At normal and moderate pressure drops through gas-gas heat exchanger 8 of 0.5 bar or less, the output from gas turbine 15 can increase by more than the power consumed in compressor 35. Thus, a net increase in output from the system is achieved. This may among other things be explained by a reduction in the amount of gas being cooled in trim cooler 12. A larger amount of energy remains in the system, and is instead used in gas turbine 15.

Example 5

Figure 5 shows a fifth preferred embodiment of the present invention. This embodiment is based on the embodiments described in examples 1, 2 and 3, with the added feature that part of the energy in the outlet gas from the combustion chamber 6 is utilises to heat water and produce steam in a heat exchanger 36, placed between combustion chamber 6 and gas-gas heat exchanger 8. A significant part of the energy in the produced steam is used to drive a steam turbine. How much of the heat in the combustion chamber that is to be transferred to the steam system (not shown) and steam turbines via heat exchanger 36, and how much is to be fed to gas-gas heat exchanger 8, is a question of optimisation and dimensioning.

A significant advantage of heat exchanger 36 is the fact that it contains evaporating water. This prevents high temperatures in the construction materials. Thus the outlet gas from the combustion chamber 6 can be relatively hot, and a significant part of the oxygen that is fed to the combustion chamber 6 with the air in pipe 5 may be combusted. The temperature in the outlet gas from combustion chamber 6 that is fed to gas-gas heat exchanger 8 via heat exchanger 36 is still moderate. Thus, an increased concentration of CO_2 and a reduced total volume flow of gas to the contacting device 13 are achieved.

For further optimisation, heat exchangers 12,17 and 27, as well as heat from intercoolers in the CO_2 compression plant 28, can be used in order to conserve residual heat. In this manner, residual heat in these gas and liquid volumes may be used to heat, or possibly evaporate or superheat water, and thereby to run steam turbines (not shown). For this embodiment, theoretical calculations show an optimum yield of electric energy

of from about 45% to over 50% of the total thermal energy liberated during combustion in combustion chamber 6, all depending on size of system and choice of optimisation solutions.

Example 6

Figure 6 shows a sixth preferred embodiment of the present invention. This embodiment is based on the embodiment described in example 5, with the addition of a further combustion chamber 37 being used between heat exchanger 36 and gas-gas heat exchanger 8. This increases the possibilities for optimising the amount of heat to be transferred to a steam system (not shown) via heat exchanger 36, and how much is to be fed to gas-gas heat exchanger 8, and thereby gas turbine 15, while at the same time taking into consideration the temperature limitations of the materials and the desire for a maximum concentration of CO_2 in the outlet gas from the combustion chambers.

In one design, the temperature requirement in gas-gas heat exchanger 8 is reduced by using a combustion chamber (not shown) between gas-gas heat exchanger 8 and gas turbine 15. The temperature of the gas to the gas turbine may then be raised by for example 50 to 150°C in this combustion chamber. This will increase the output from the gas turbine, while reducing the requirement for heating in gas-gas heat exchanger 8. A condition of this design is that a bit more CO_2 is absorbed in contacting device 13, so as to maintain the total CO_2 emission from the gas turbine 15 at an acceptable level.

In all the examples shown it may be necessary to include filters (not shown), for instance in flue gas pipe 10 or gas pipe 14, in order to prevent dust and other unwanted particles and/or drops from becoming entrained in the gas stream. It is particularly important to prevent particles or drops from reaching the gas turbine 15

The term air, as used in this description and these claims, also includes oxygenated air.

C l a i m s

1.

A method for controlling the CO_2 content in flue gas from thermal power plants, in the case of combustion of carbon or other carbon-containing fuel and air, in which the combustion takes place in a combustion chamber (6) and the combustion gas is separated into a CO_2 –rich flue gas and a gas with a low CO_2 content, and where the CO_2 –rich flue gas is then treated in a manner so as not to let CO_2 escape to the environment, w h e r e i n

compressed air and fuel is fed to the combustion chamber (6) in which combustion takes place at an elevated pressure,

the flue gas from the combustion is cooled and passed through a pressurised contacting device (13) where CO_2 from the combustion is absorbed by an absorbent,

the non-absorbed gas is led away as a stream with a low CO_2 content, compressed air is added, it is heated and depressurised across a gas turbine (15) before being released to the environment, and

the absorbent is regenerated and recycled or removed for disposal.

2.

Method according to Claim 1, w h e r e i n the absorbent from the contacting device (13) is passed to a desorption device (18) that is at a lower pressure and/or higher temperature than the contacting device, such that CO_2 is desorbed and a CO_2 –rich flue gas is led away for further treatment, and the absorbent is recycled through the contacting device (13).

3.

Method according to claim 1 or 2, w h e r e i n the flue gas from the combustion is cooled through heat exchange with compressed air and the stream with a low CO_2 content from the contacting device (13), before the flue gas is fed to the contacting device(13).

4.

Method according to one or more of the preceding Claims, w h e r e i n the gas stream with a low CO_2 content from the contacting device is depressurised across a

turbine (15) after the gas has been heated by the flue gas from the combustion chamber (6) in a heat exchanger (8).

5.

Method according to one or more of Claims 1 to 5, w h e r e i n the absorbent is a liquid, such as water, an amine solution or an inorganic solution.

6.

Thermal power plant for combustion of carbon or carbon-containing materials, comprising combustion means in which the carbon is combusted with air, a flue gas pipe for leading the combustion gas from the combustion chamber (6) to a contacting device (13) in which the flue gas is contacted with an absorbent that mainly absorbs CO_2 and mainly does not absorb the other gases in the flue gas, a gas pipe (14) for the non-absorbed gas stream with a low CO_2 content from the contacting device and means of depressurising the gas stream with a low CO_2 content before releasing it to the environment, as well as means of transporting absorbent with dissolved CO_2 from the contacting device for disposal, or means of desorption of CO_2 for recycling of the absorbent, w h e r e i n is comprised

a combustion chamber (6) that is designed for combustion of air and fuel at an elevated pressure,

a contacting device (13) containing an absorbent that absorbs CO_2, and in which the remaining gases from the combustion are mainly not absorbed, so as to form a gas stream with a low CO_2 content and a stream of CO_2-rich absorbent,

means (8, 11, 12) of cooling the flue gas from the combustion before this reaches the contacting device (13), as well as for heating the stream with a low CO_2 content, and a turbine (15) for depressurisation of the stream with a low CO_2 content, where the turbine drives a generator (16) for production of electric power.

7.

Thermal power plant according to Claim 6, w h e r e i n the pressure in the combustion chamber (2) is between 1.5 and 30 bar, preferably between 10 and 18 bar.

8.

Thermal power plant according to Claim 6 or 7, w h e r e i n is also comprised means (7) of adding compressed air to the stream with a low CO_2 content, before this is depressurised across the turbine (15).

9.

Thermal power plant according to any of Claims 6 to 8, w h e r e i n is also comprised means (18) of regenerating the absorbent so as to form a CO_2-rich stream that may be compressed for disposal or sale, and where the absorbent may be returned to the contacting device (13).

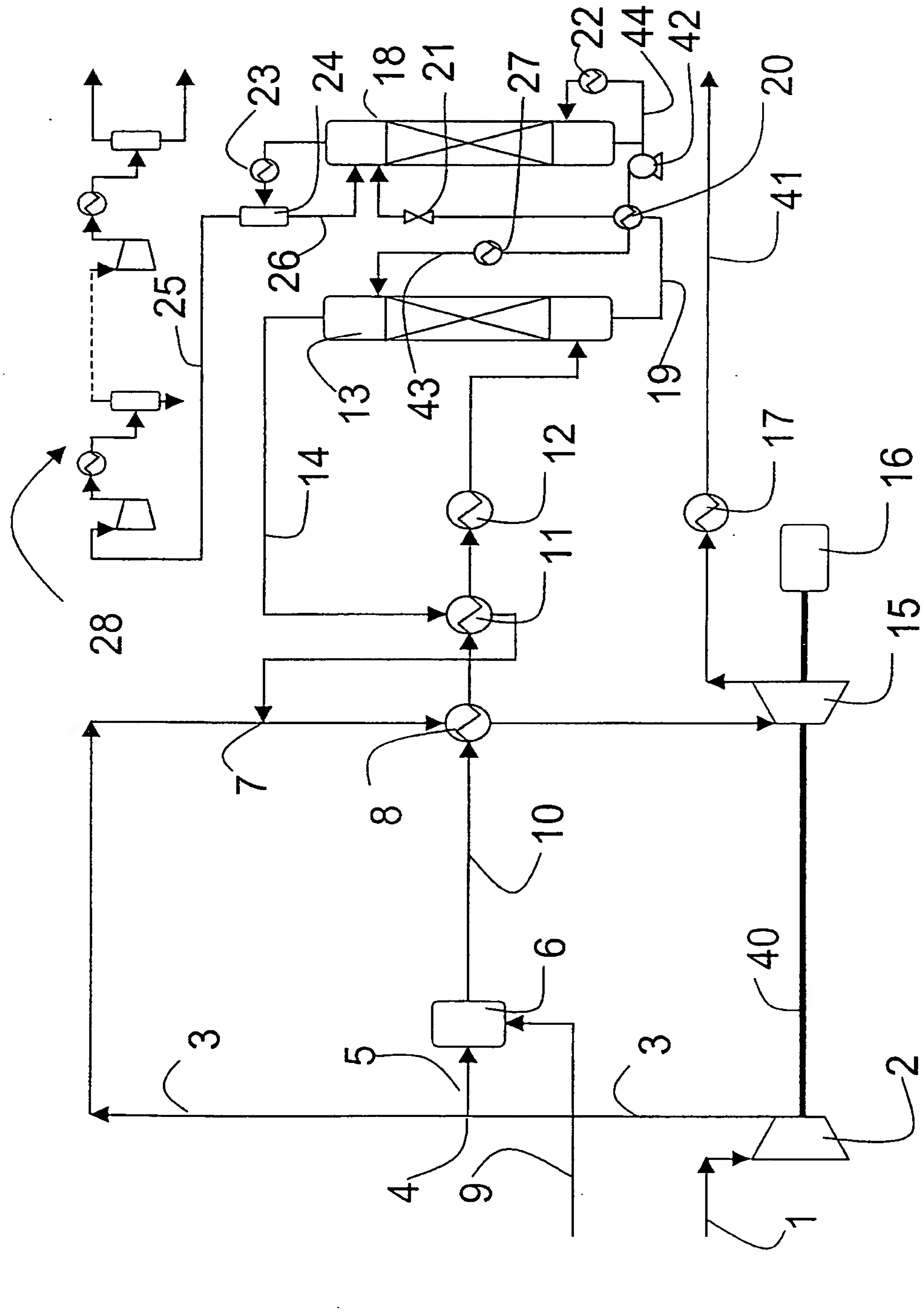
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FIG. 1

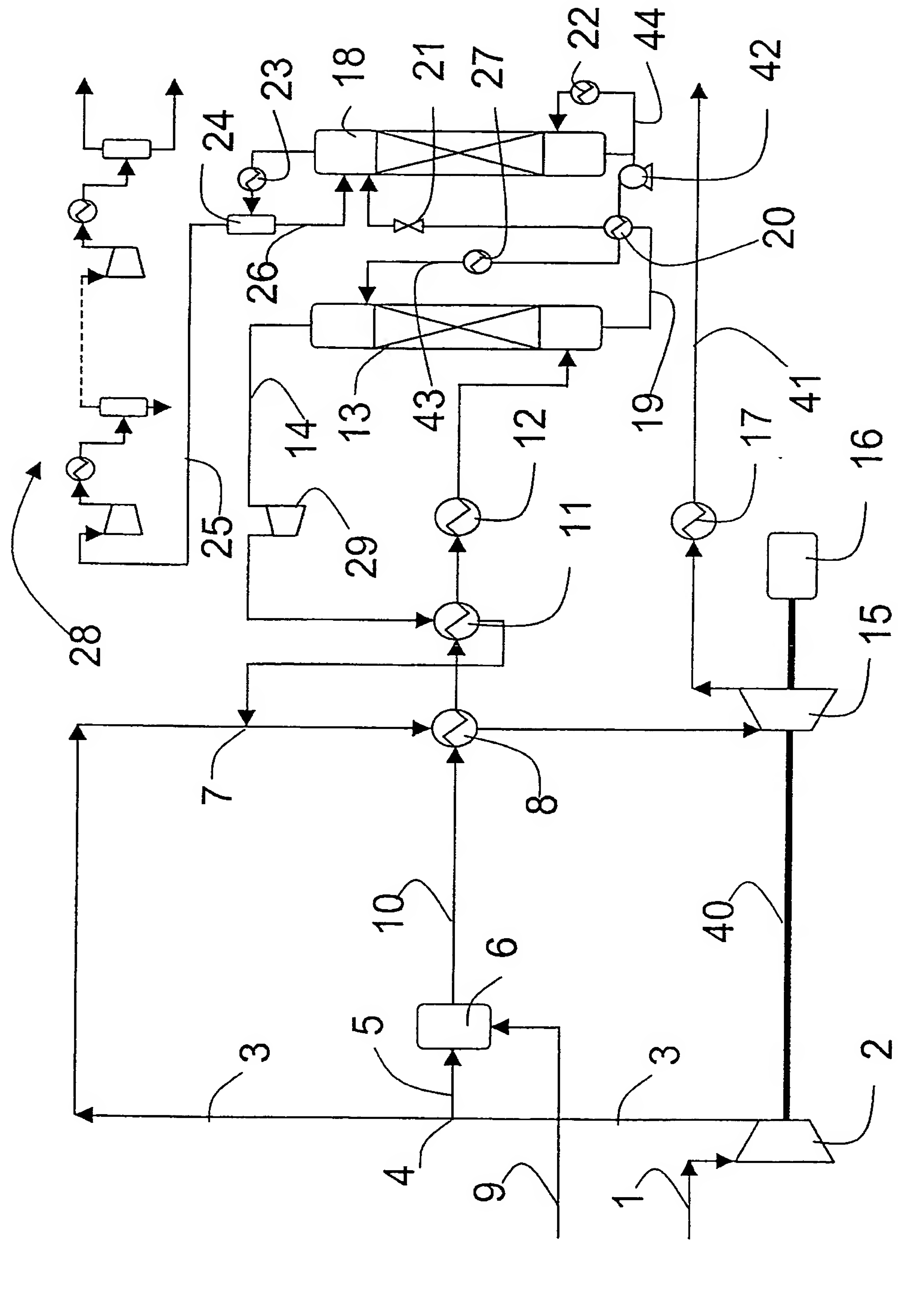
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FIG. 2

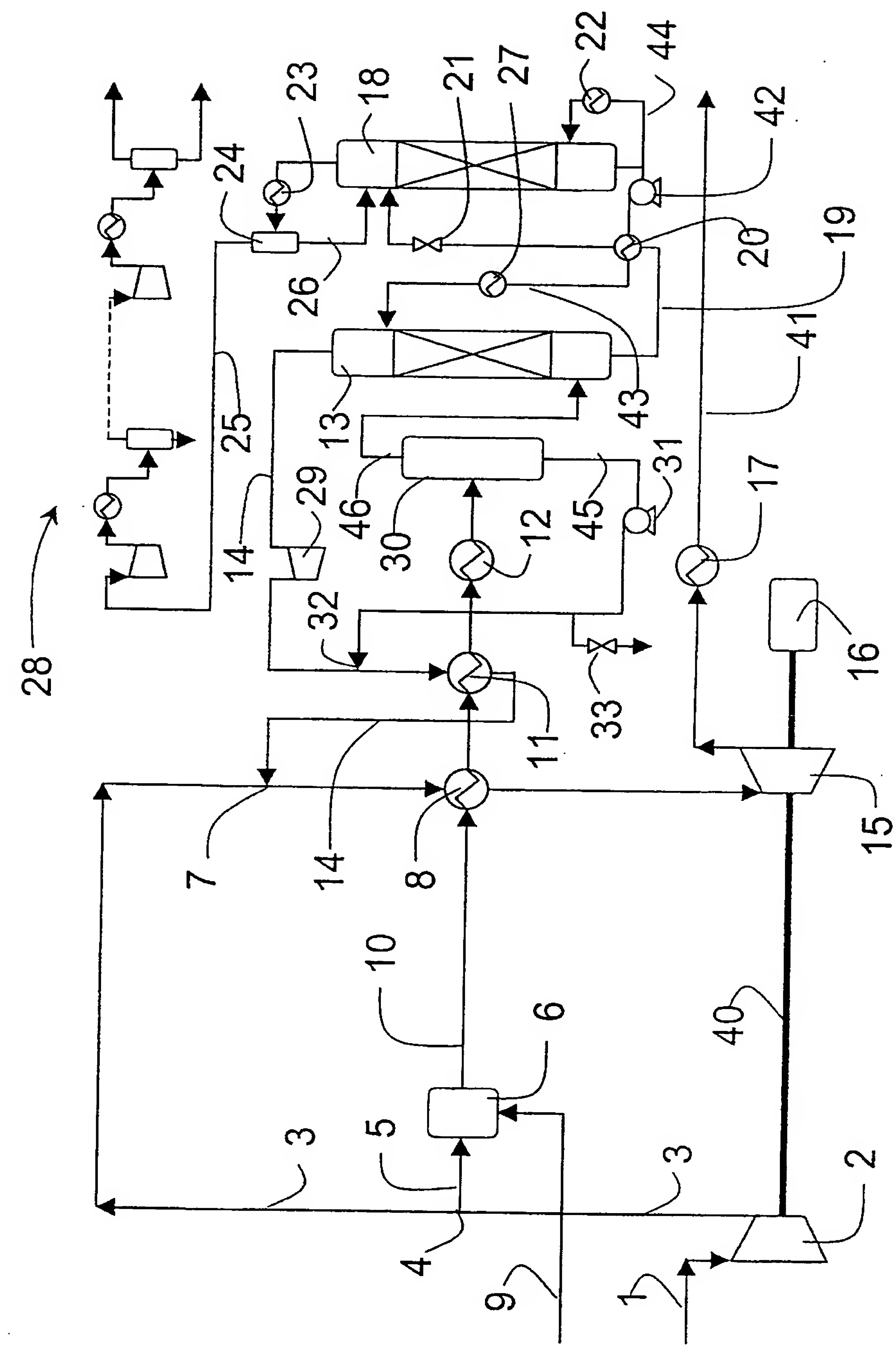
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FIG. 3

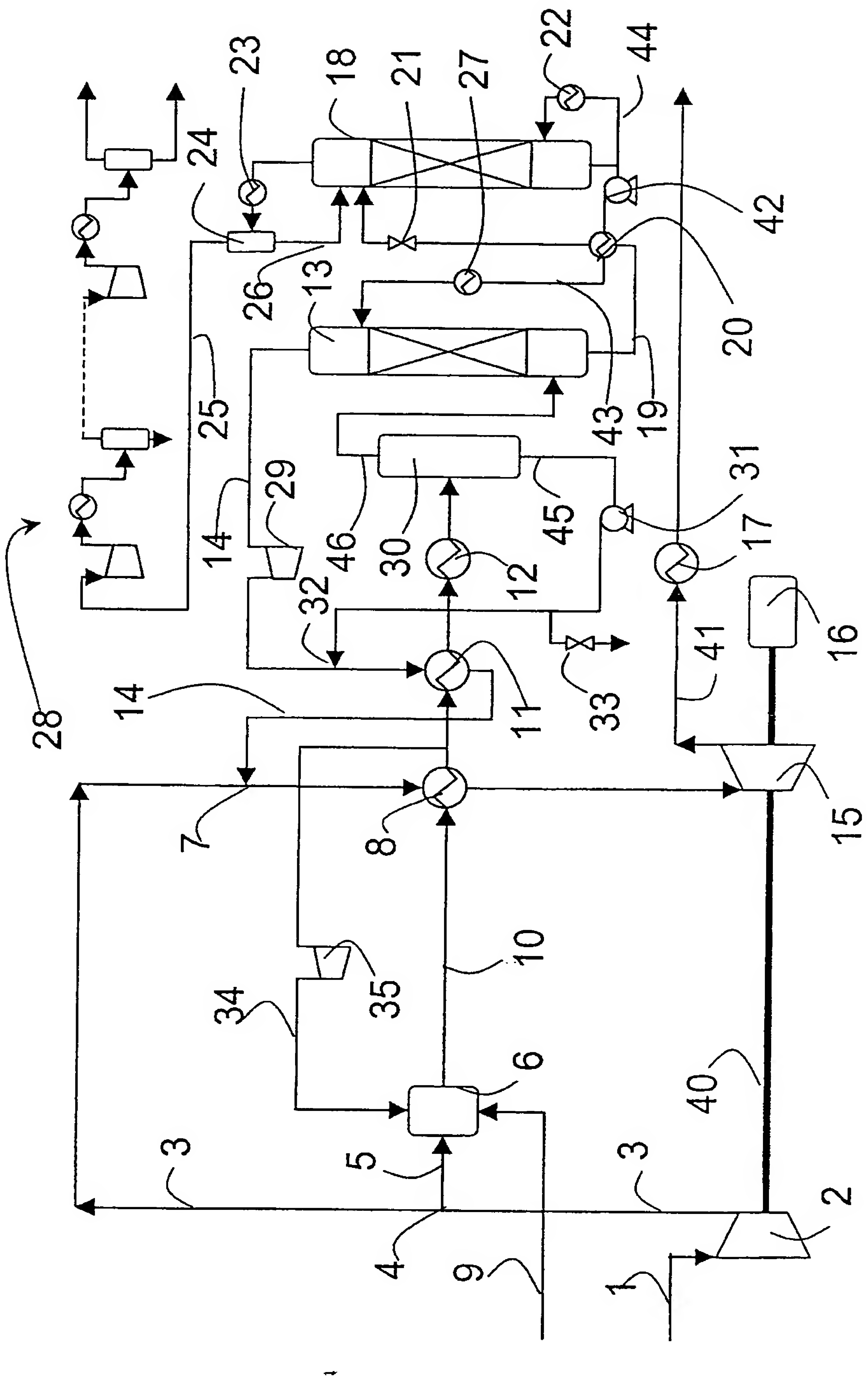
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FIG. 4

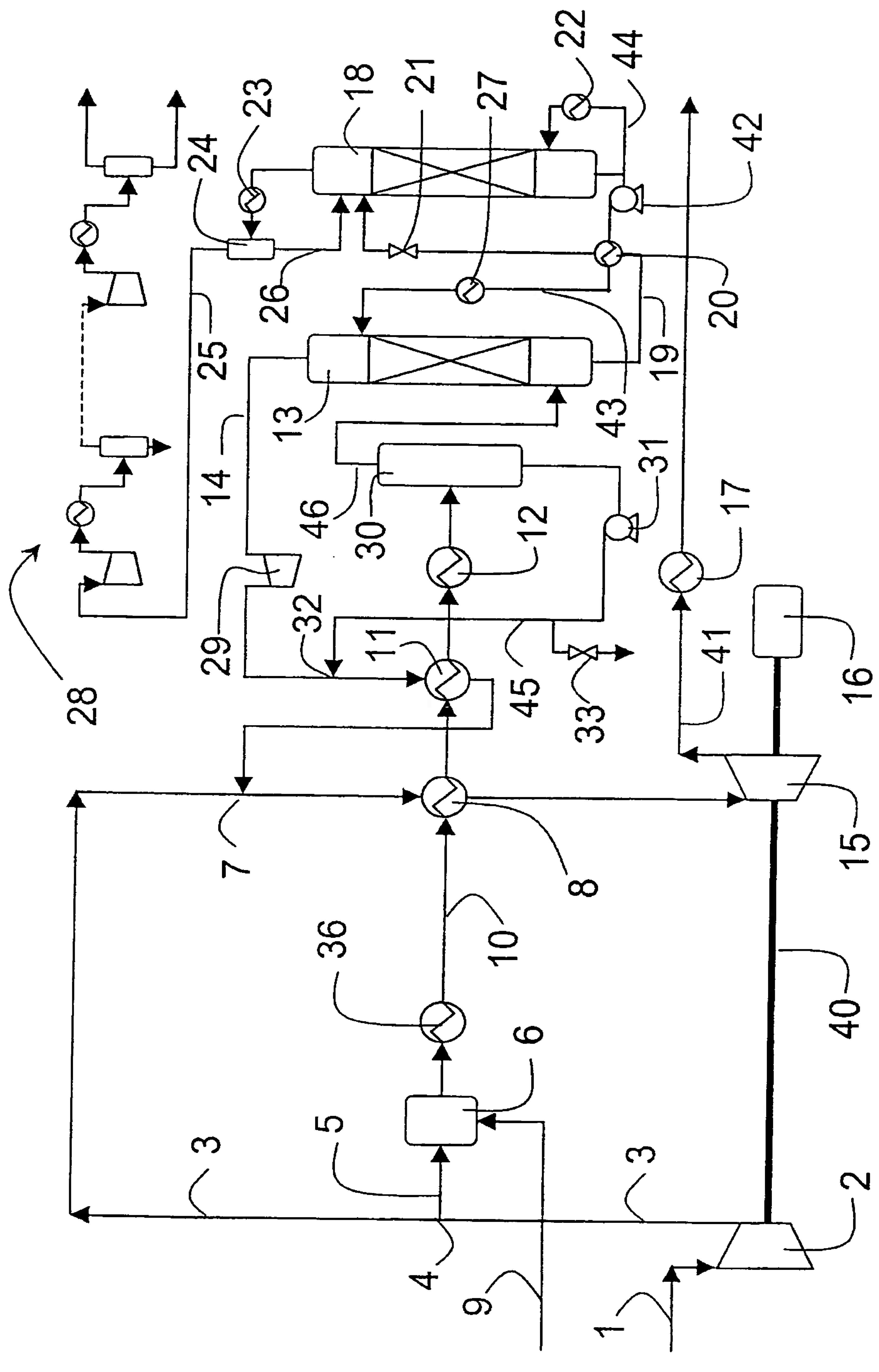
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FIG. 5

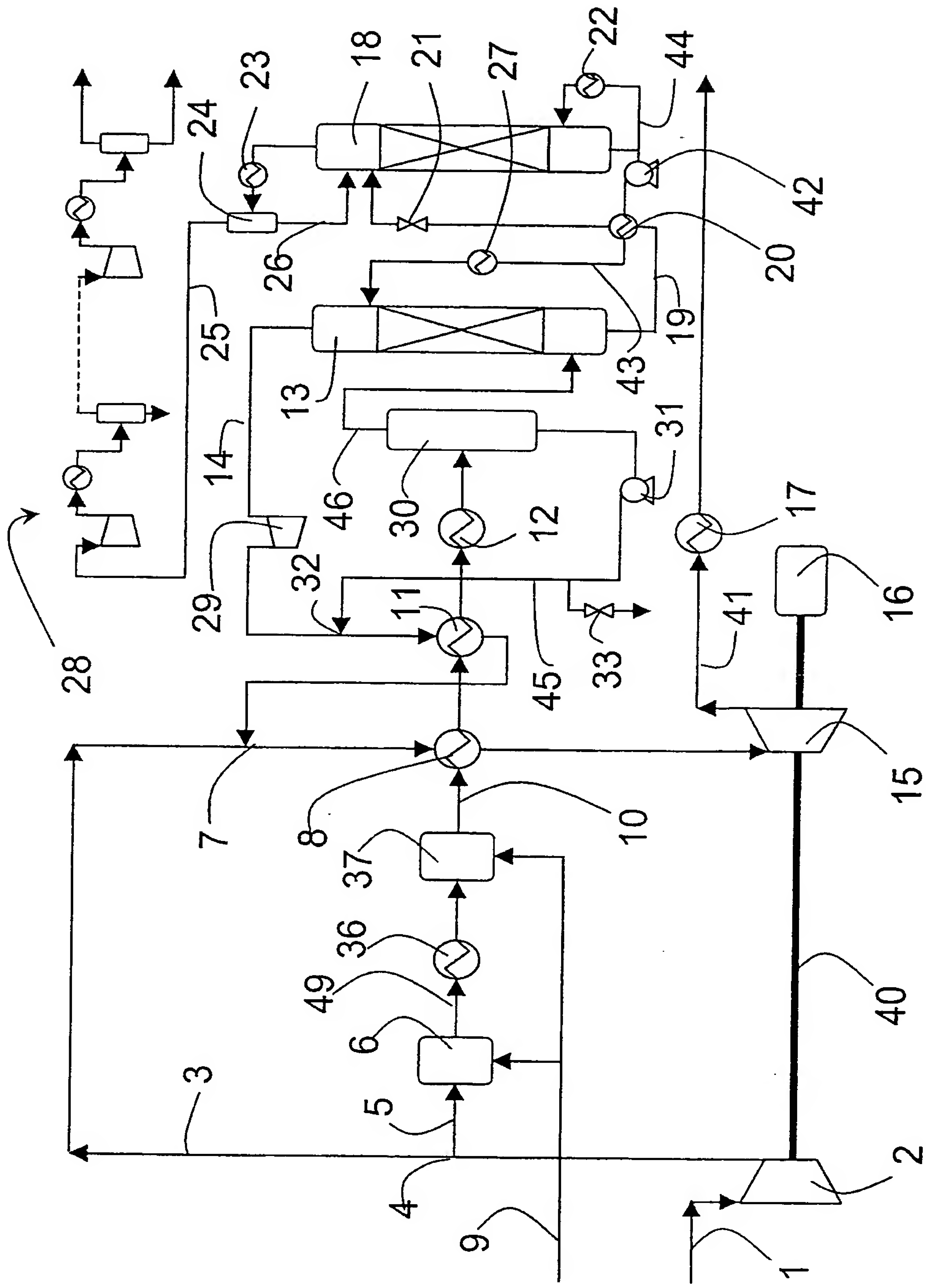

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FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 00/00100

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: B01D 53/14, B01D 53/62

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: B01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0551876 A2 (THE KANSAI ELECTRIC POWER CO., INC. ET AL), 21 July 1993 (21.07.93) --	1-9
A	WO 9521683 A1 (KVÆRNER ENGINEERING A.S.), 17 August 1995 (17.08.95) -- --------	1-9

☐ Further documents are listed in the continuation of Box C.   ☒ See patent family annex.

* Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" erlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 August 2000	17 -08- 2000
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Bertil Dahl/ELY Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

Information on patent family members

02/12/99

International application No.
PCT/NO 00/00100

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